NERVOUS SYSTEM

Physiology

PHYSIOLOGY

1. Resting Membrane Potential
2. Depolarization
3. Propagation of action potential
4. Repolarization/Hyperpolarization

- No Na+ = No action potential
- Neurons communicate by neurotransmitters that can either excite or inhibit the next cell

VIDEOS

- Na/K Pump
- Action Potential
- 3D animation with synapse
- Microscopic View of Neuron
- Connection between Neurons – how does it happen

PHYSIOLOGY OF NERVE IMPULSES

* Impulse can be sent from the dendrites down the axon of the neuron because of irritability and conductivity

A) Conductivity

- Neurotransmitters – 50 known
  - Small, rapidly acting molecules although some can be slow acting
  - Can cause an excitatory or inhibitory effect on the next neuron
    - Ex: Acetylcholine – used in muscle contraction, Dopamine, Serotonin, Epinephrine

PHYSIOLOGY OF NERVE IMPULSES

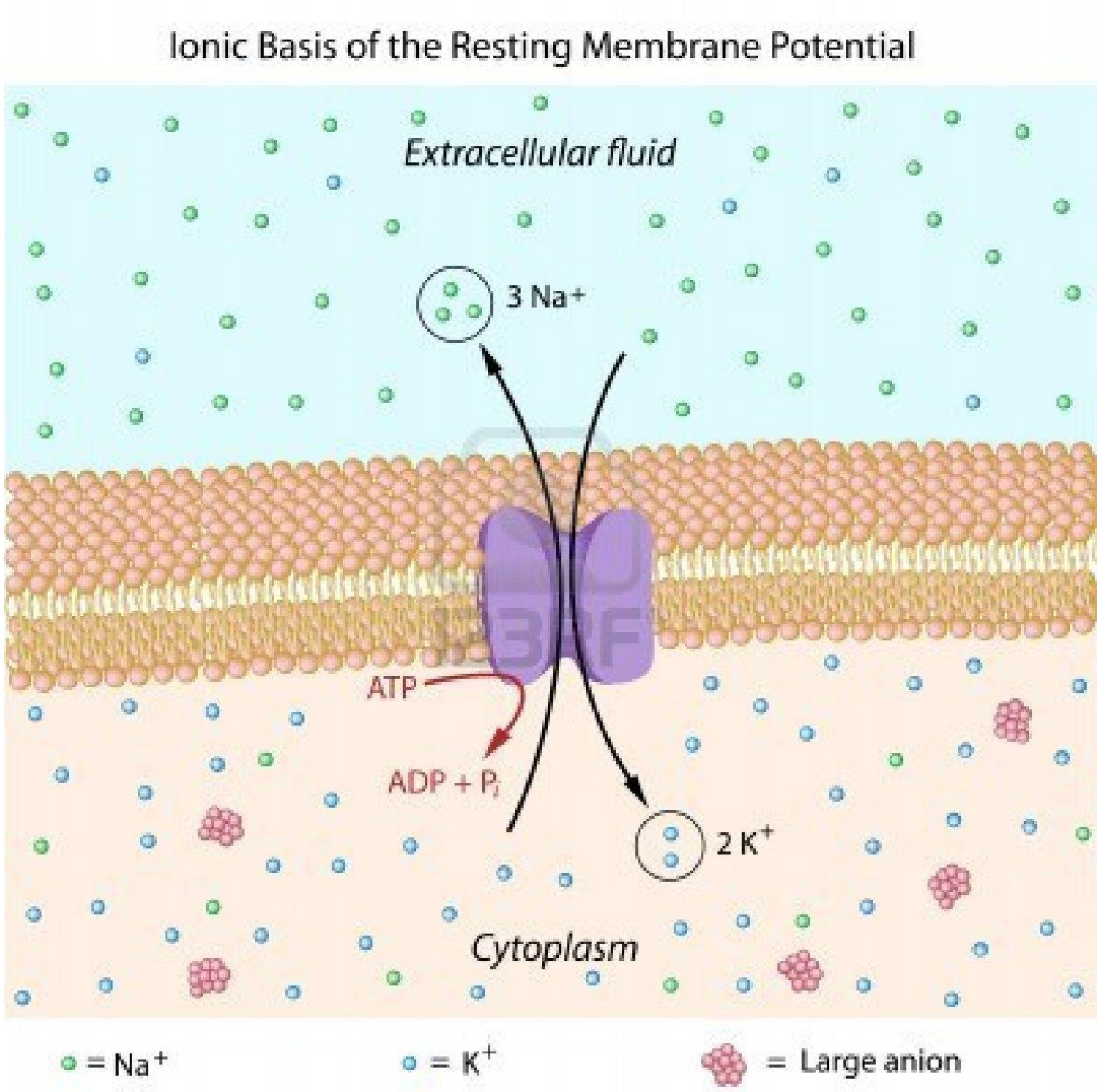
B) Irritability

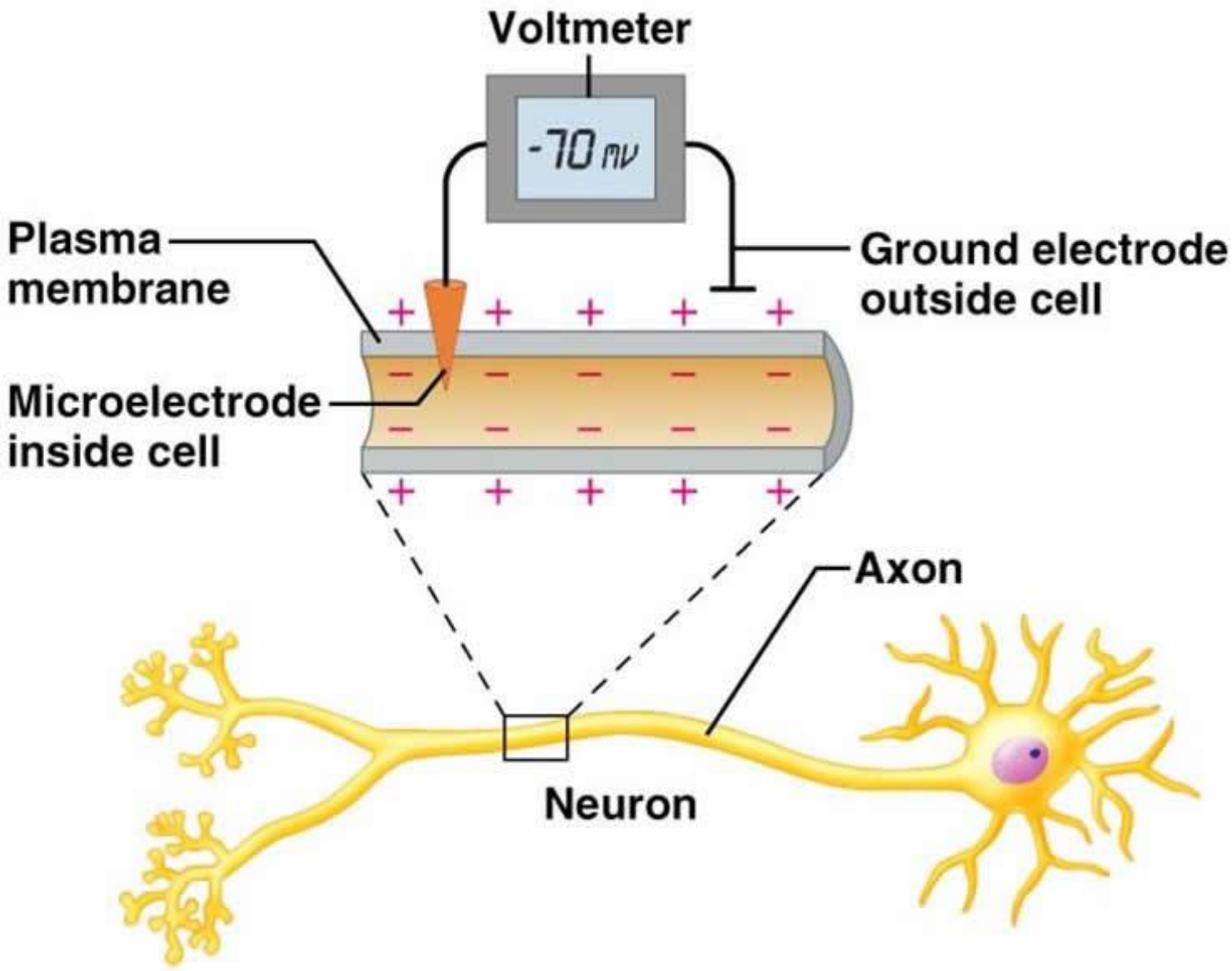
1. Resting membrane potential –

- Starts with more K^+ on the inside and more Na^+ on the outside
  - Think: Salty banana

- Ion differences and the presence of large proteins on the inside of the cell makes the outside extracellular fluid more positive than the inside of the cell in the cytoplasm (-70 mV)

- Only a few of the K^+ protein channels are open at this time and the Na^+ channels are closed

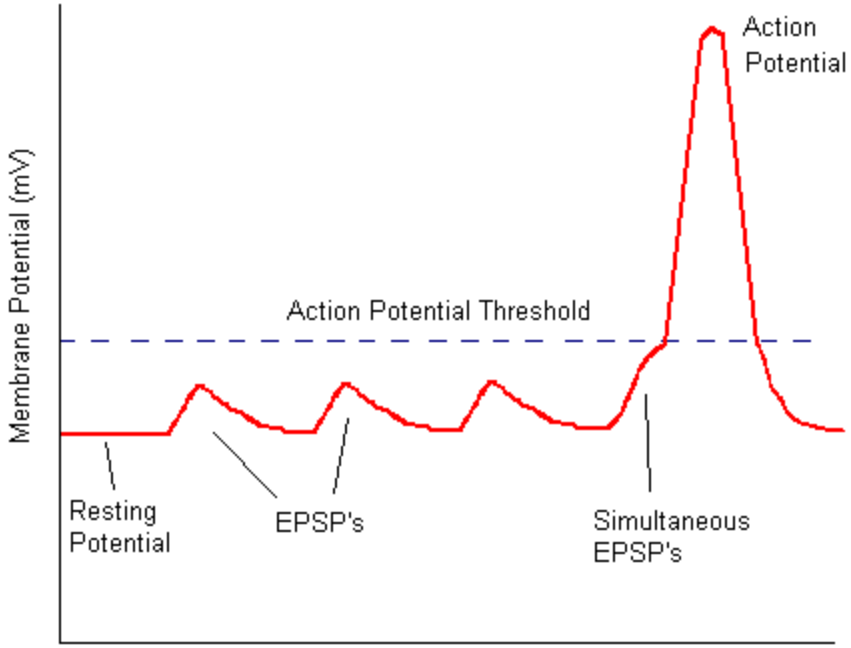

Ionic Basis of the Resting Membrane Potential
Extracellular fluid
3 Na+
ATP
ADP + Pi
2 K+
Cytoplasm
= Na+
= K+
= Large anion


Voltmeter
-70 mv
Plasma membrane
Ground electrode outside cell
Microelectrode inside cell
Axon
Neuron

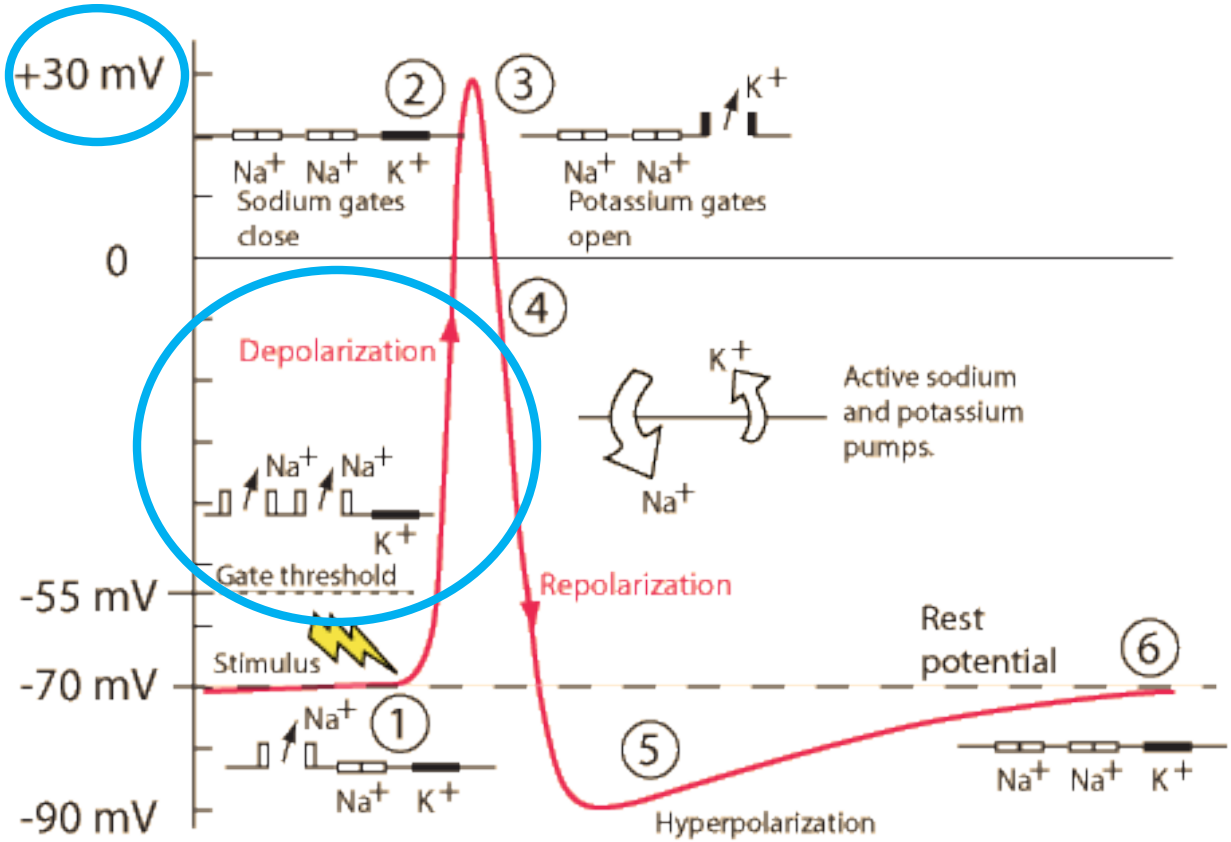
- **Stimuli**: causes the neuron to become active
  - Ex) light, sound, pressure, neurotransmitter
- Signal starts at the dendrites and the cell body will send the signal beginning at the axon hillock if a large enough stimulus occurs

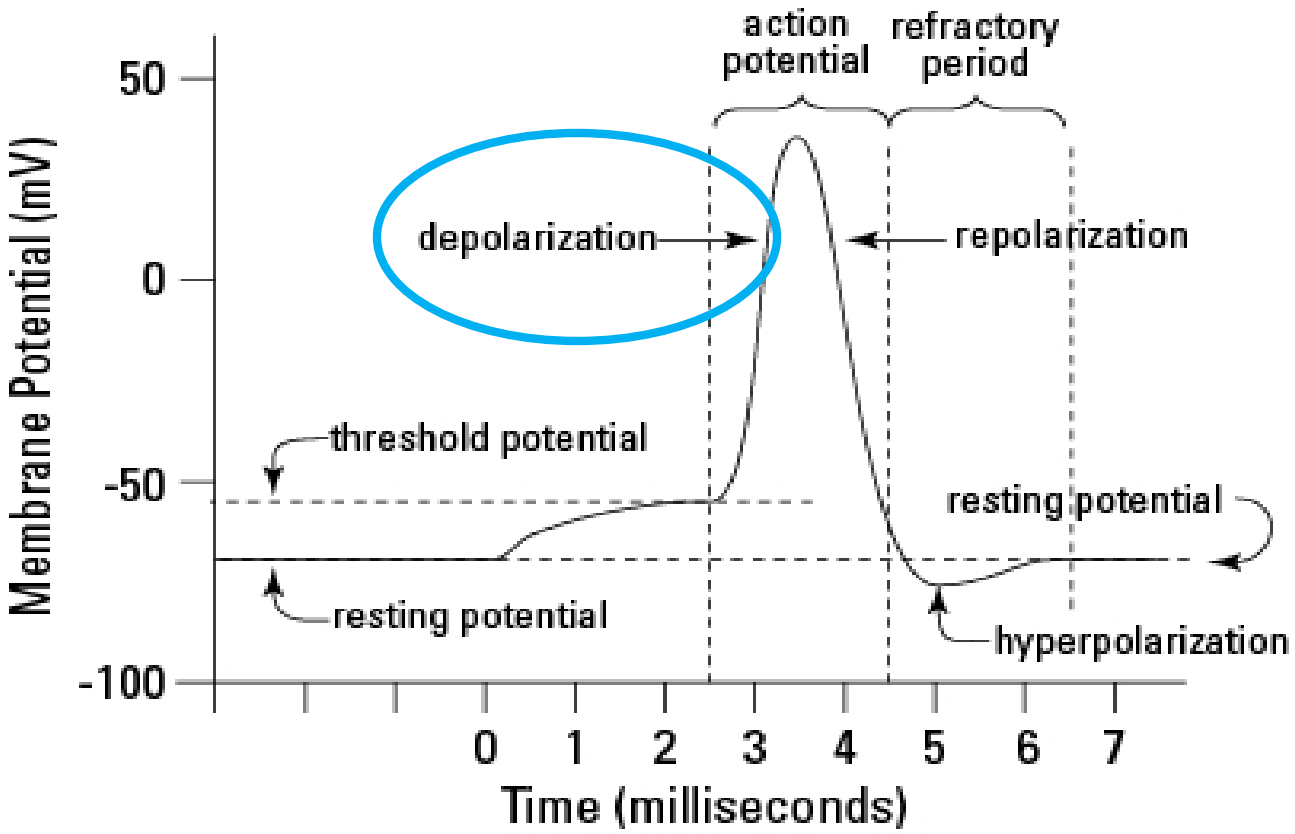
- Result: permeability of cell membrane changes briefly

- **<u>Threshold</u>** = large enough stimulus to trigger an action potential and cause the Na^+ channels to open (-55mV)



2. **Depolarization**: Na^+ moves into the cell when the Na^+ channels open and changes polarity to positive inside and negative outside

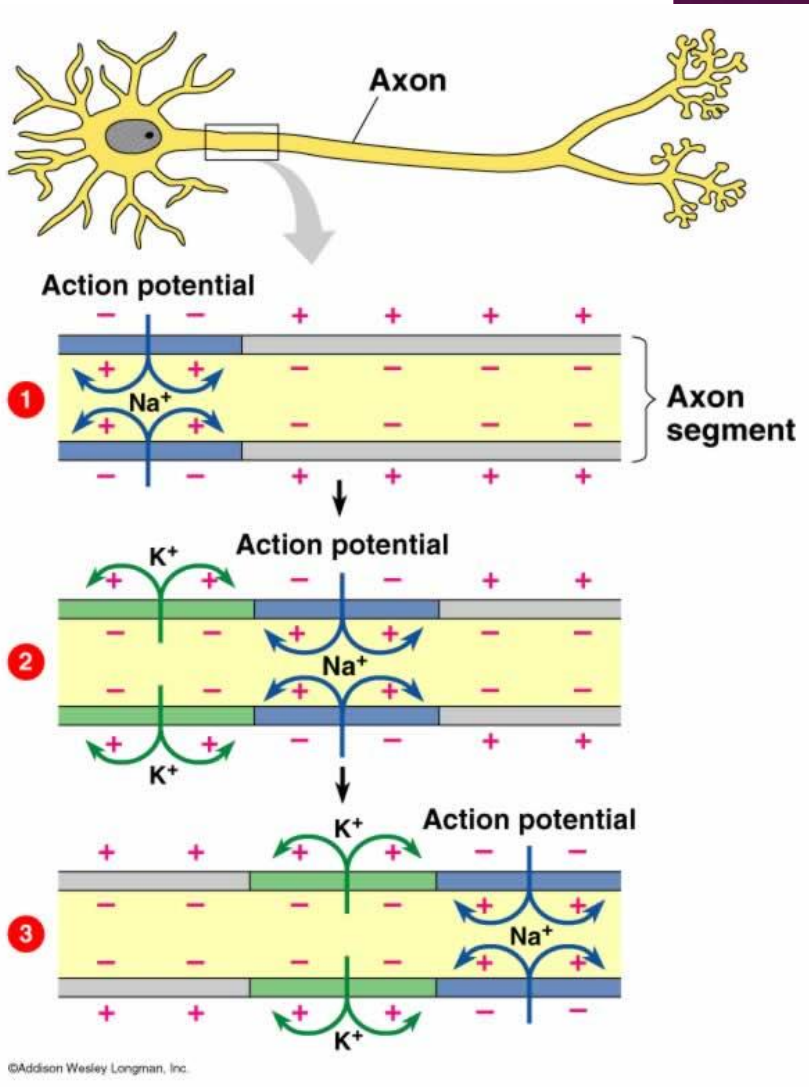



action potential
refractory period
50
0
-50
-100
depolarization
repolarization
threshold potential
resting potential
resting potential
hyperpolarization
Membrane Potential (mV)
0 1 2 3 4 5 6 7
Time (milliseconds)

3. Propagation of Action Potential (electrical impulse):

Neuron continues the depolarization down the axon to transmit the action potential

- **All or None Law** – once a signal starts it will continue down the entire cell membrane



4. Repolarization/Hyperpolarization:

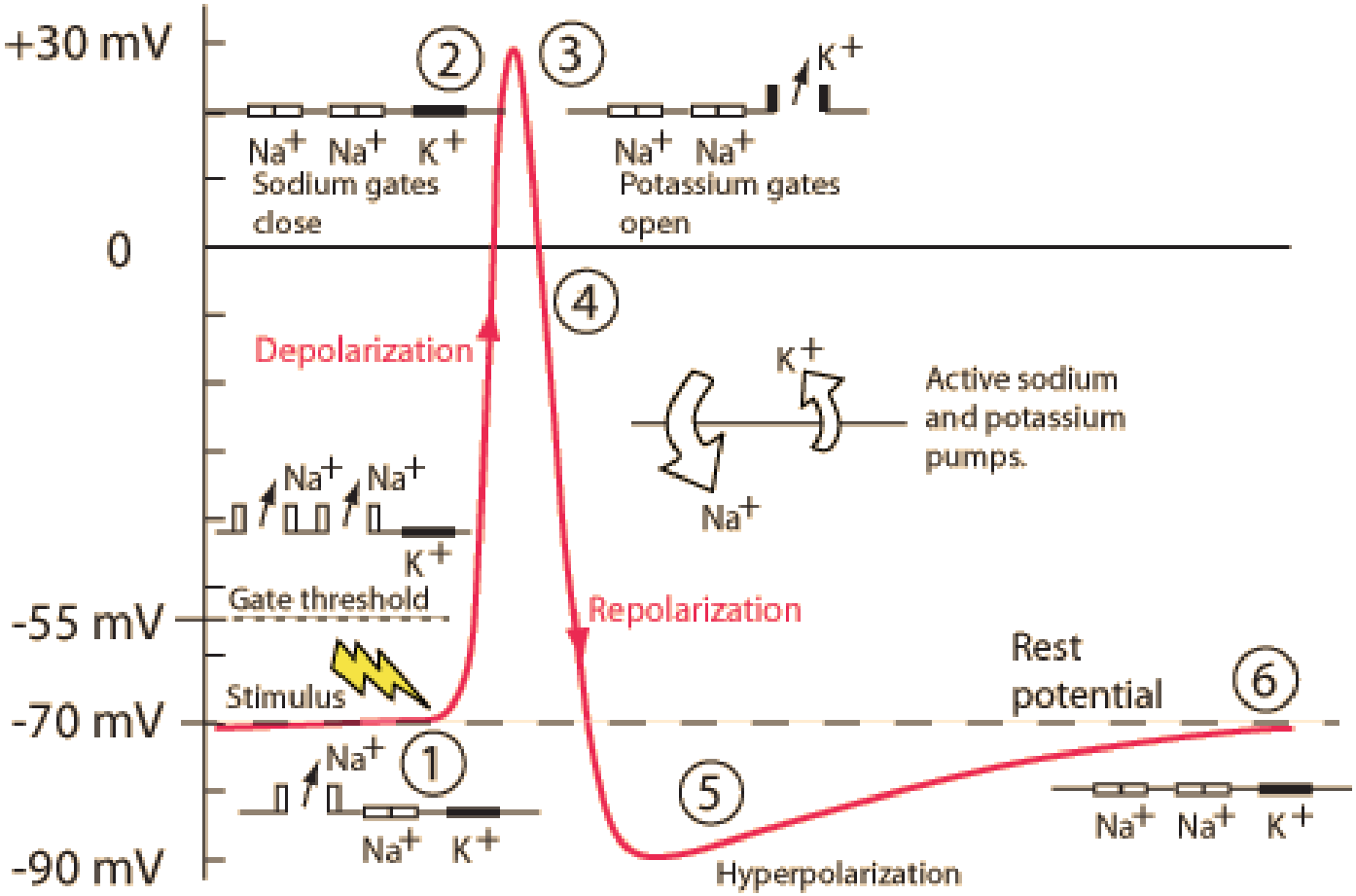
- Na^+ stops being permeable and their channels close
- Right behind the action potential, K^+ diffuses out through the K^+ channel to quickly change the charge back to positive outside and negative inside
- **Na^+/K^+ pump** restores the ion concentrations (needs ATP) back to the resting membrane potential
  - 3 Na^+ out and 2 K^+ in

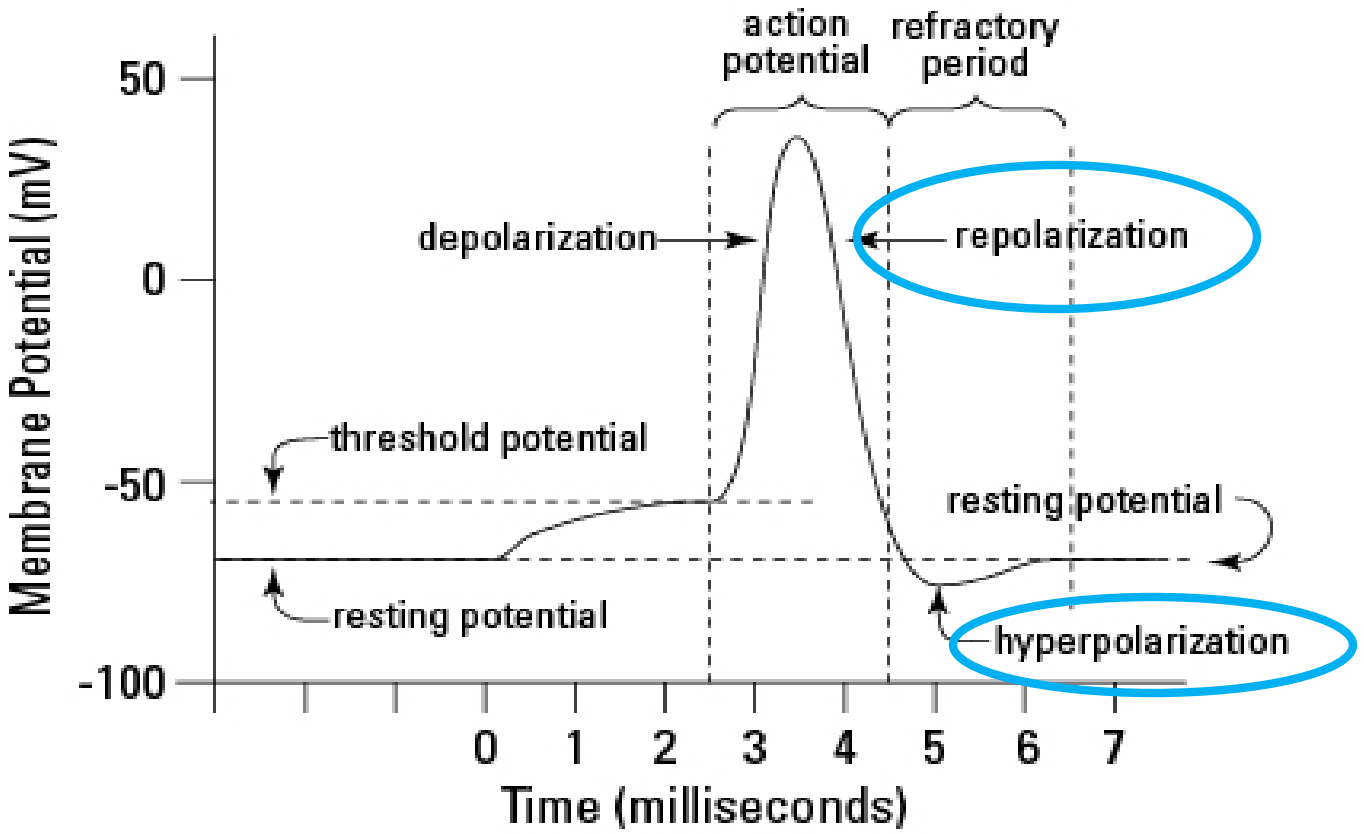
- **Hyperpolarization** = causes the membrane to become even more negative and occurs right before reaching resting membrane potential

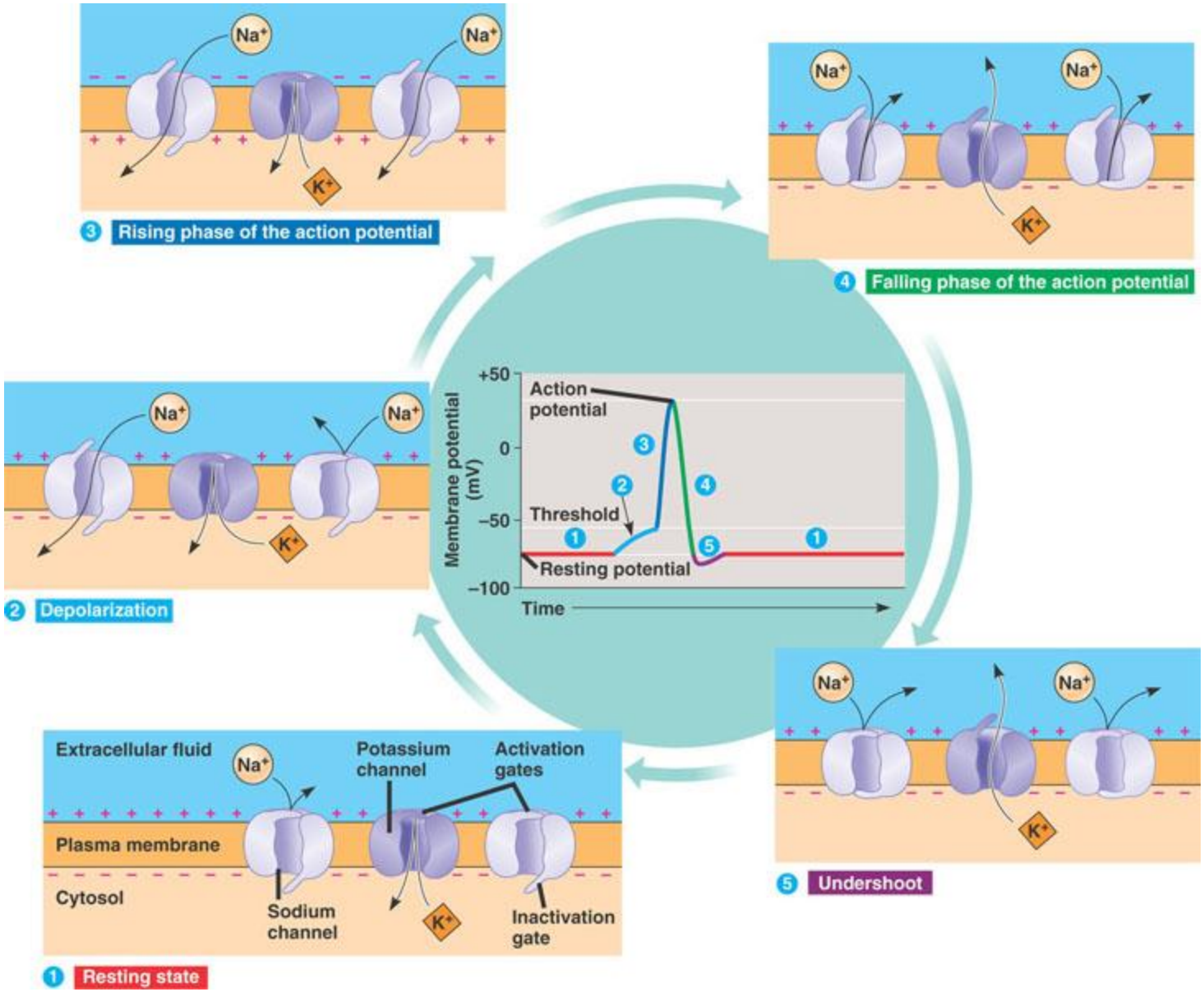
- This creates a **refractory period** where the neuron can not receive another stimulus and has to wait to send another signal

- Until repolarization occurs, neuron can't transmit another impulse

- No Na^+ entry = No action potential




action potential
refractory period
50
0
-50
-100
Membrane Potential (mV)
depolarization
repolarization
threshold potential
resting potential
resting potential
hyperpolarization
0
1
2
3
4
5
6
7
Time (milliseconds)


Na+
K+
3 Rising phase of the action potential
4 Falling phase of the action potential
2 Depolarization
5 Undershoot
1 Resting state
+50
0
−50
−100
Membrane potential (mV)
Action potential
Threshold
Resting potential
Time
Extracellular fluid
Plasma membrane
Cytosol
Potassium channel
Activation gates
Sodium channel
Inactivation gate

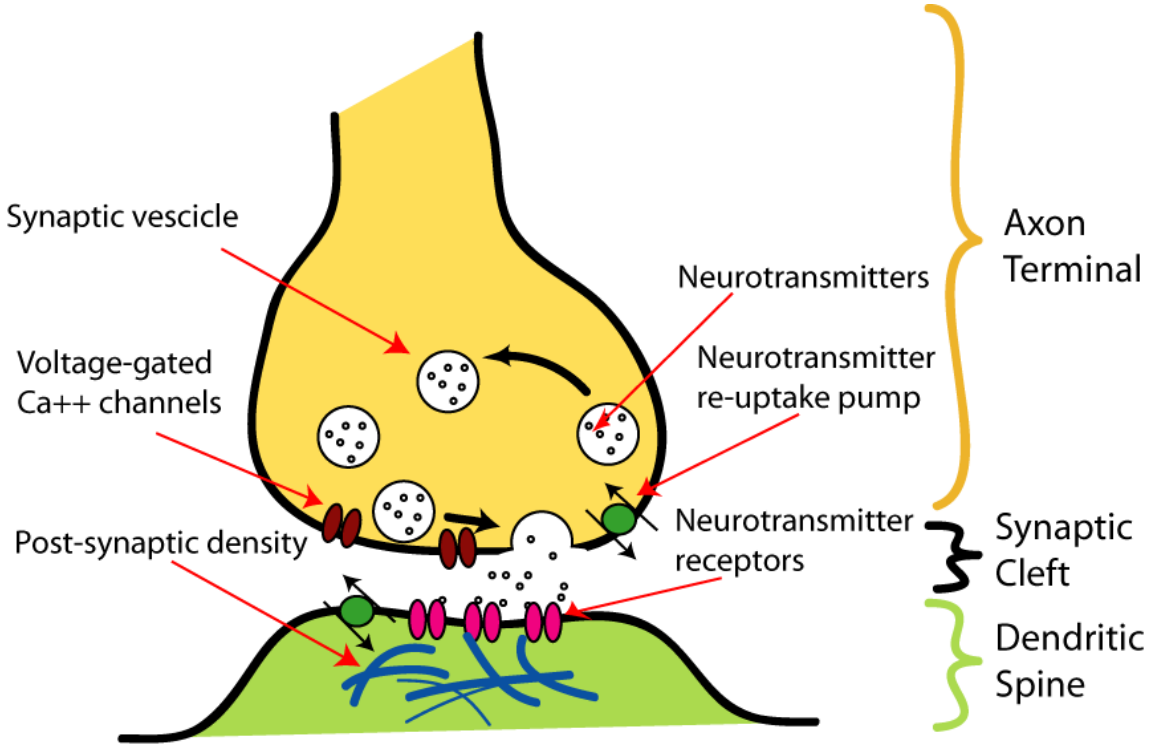
SYNAPSE

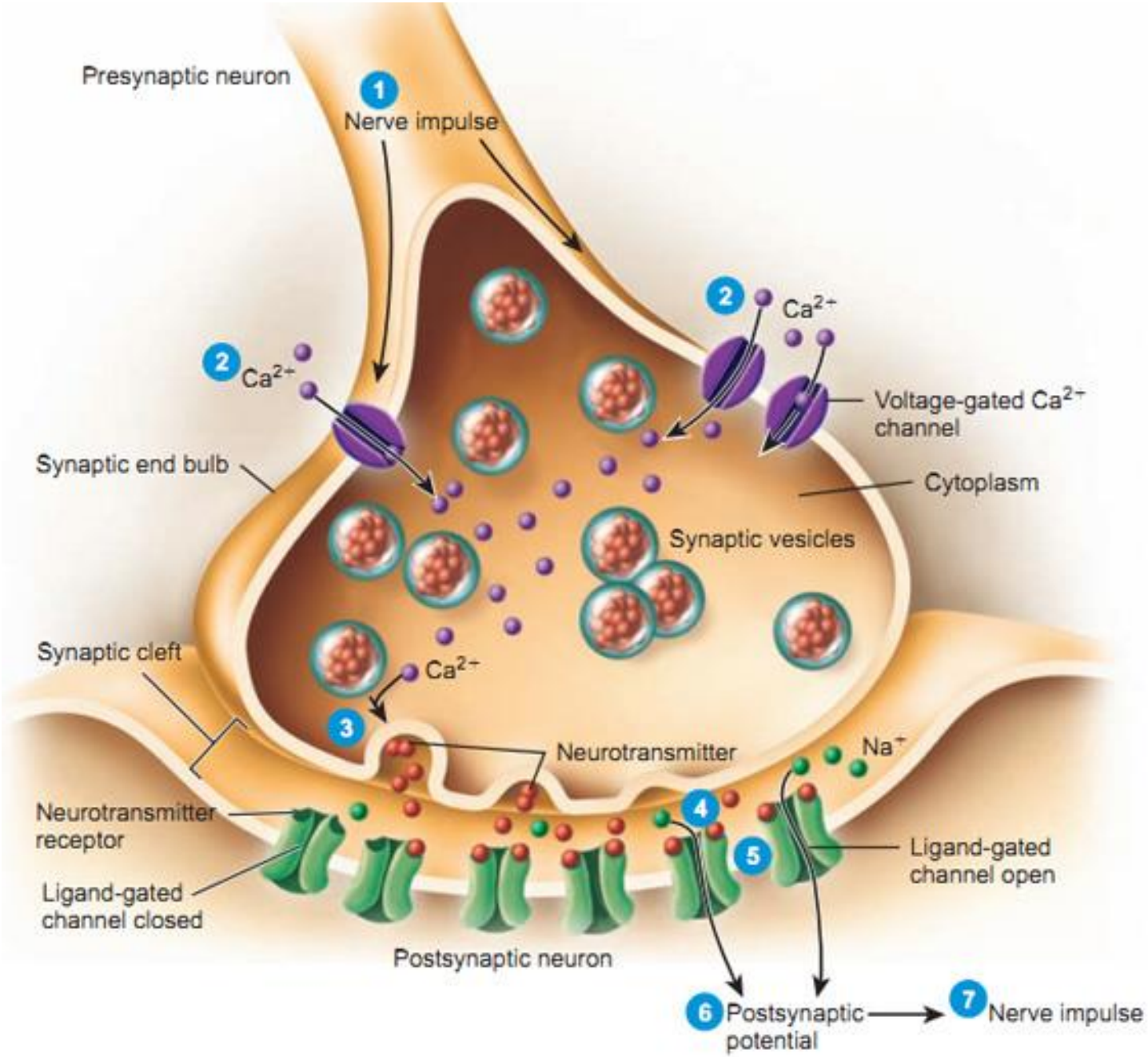
- Neurons communicate by sending electrical signals across a synapse

- Synaptic cleft – space between 2 neurons (or between a neuron and another cell)

- The electrical impulse opens a Ca^{2+} channel in the axon terminal membrane
- Ca^{2+} binds to the vesicles storing the neurotransmitters
- The vesicles fuse to the membrane and release the neurotransmitters from the pre-synaptic neuron

- Then the neurotransmitters bind to protein receptors on the post-synaptic neuron which causes another action potential
  - This continues the signal and allows cells to "talk" to each other




Presynaptic neuron
1
Nerve impulse
2
Ca^{2+}
2
Ca^{2+}
Voltage-gated Ca^{2+} channel
Synaptic end bulb
Cytoplasm
Synaptic vesicles
Synaptic cleft
Ca^{2+}
3
Neurotransmitter
Na^{+}
Neurotransmitter receptor
4
5
Ligand-gated channel open
Ligand-gated channel closed
Postsynaptic neuron
6
Postsynaptic potential
7
Nerve impulse

PROBLEMS WITH IMPULSES

- Factors affecting permeability of Na+
  - Alcohol, sedatives and anesthetics
  - Cold or continuous pressure interrupts blood circulation, so nutrients are unable to get to neurons

THE END